# DCPR Enhancements to Increase Capacity

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# Rationale / Overview

- Root Raised Cosine Filtering
  - Rationale and Advantages/Disadvantages
  - RRC Implementation considerations

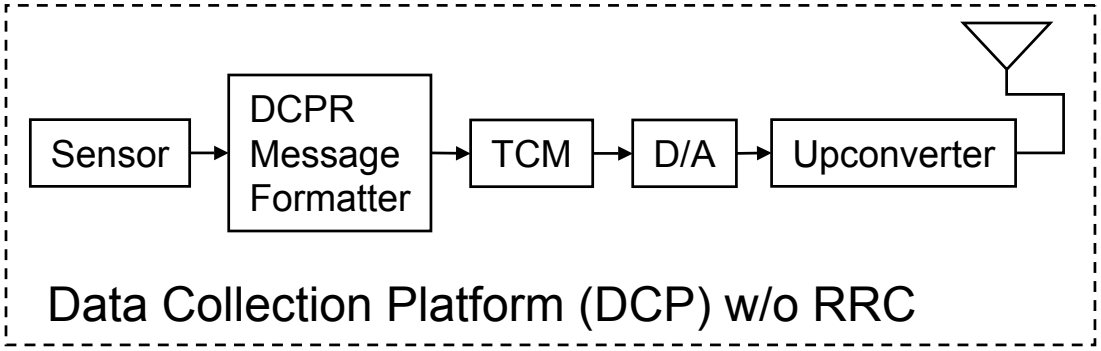
# GOES Data Collection System

- Communications link designed to relay information gathered from data collection platforms (DCPs) located throughout Western Hemisphere
- 400 KHz bandwidth allocated for the the GOES DCS communications link
  - Multiple Access system
    - 200 FDMA channels @ 1500 Hz
    - 33 FDMA channels @ 3000 Hz
  - Three data rates supported per channel
    - 100 bps BPSK modulation @ 1500 Hz
    - 300 bps 8-PSK TCM modulation @ 50 dBm (max) and 1500 Hz
    - 1200 bps 8-PSK TCM modulation @ 53 dBm (max) and 3000 Hz
  - Channels alternate between two satellites
- DCP Messages comprise of a header + information
  - Information typically formatted using ASCII text
    - Binary and Pseudo-binary also possible formats for information

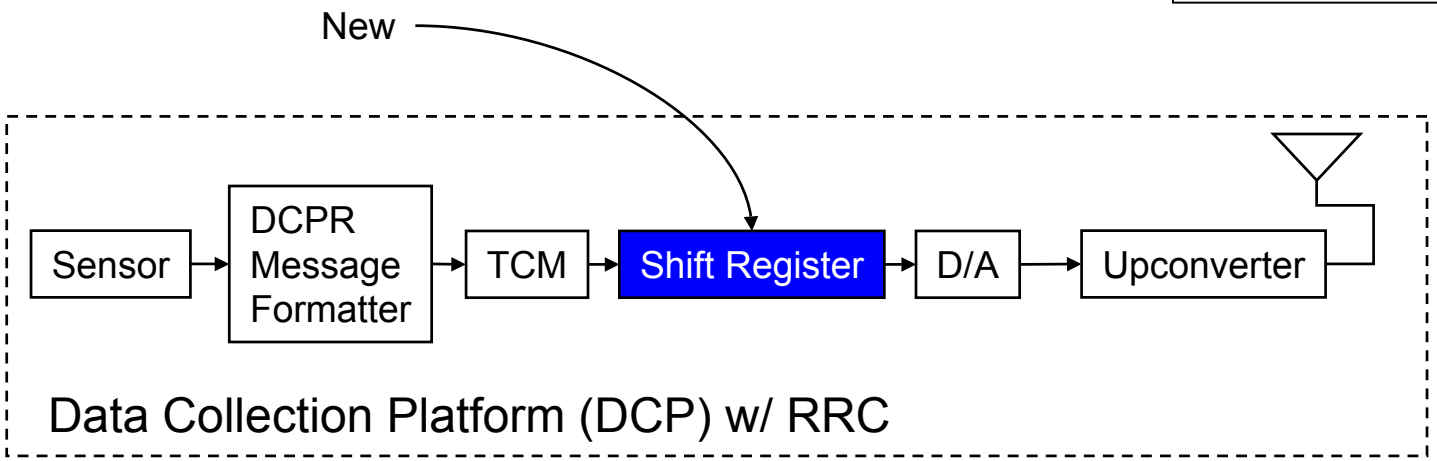
# Advantages/Disadvantages to RRC

- Advantages / Rationale
  - RRC filtering will increase the spectral efficiency of the DCPR system
    - Spectral Efficiency = bits per second / Bandwidth (Hz)
  - Increase in spectral efficiency results in increased capacity of the DCPR communications system as more DCPs would be able to be supported
- Disadvantages
  - Additional users on GOES DCPR channel requires power levels be addressed
    - Need to maintain same satellite output power as seen today without impacting user $E_B/N_0$
  - RRC waveforms will have higher peak to average ratios compared to the current (rectangular pulse) waveforms

# Where does RRC fit?

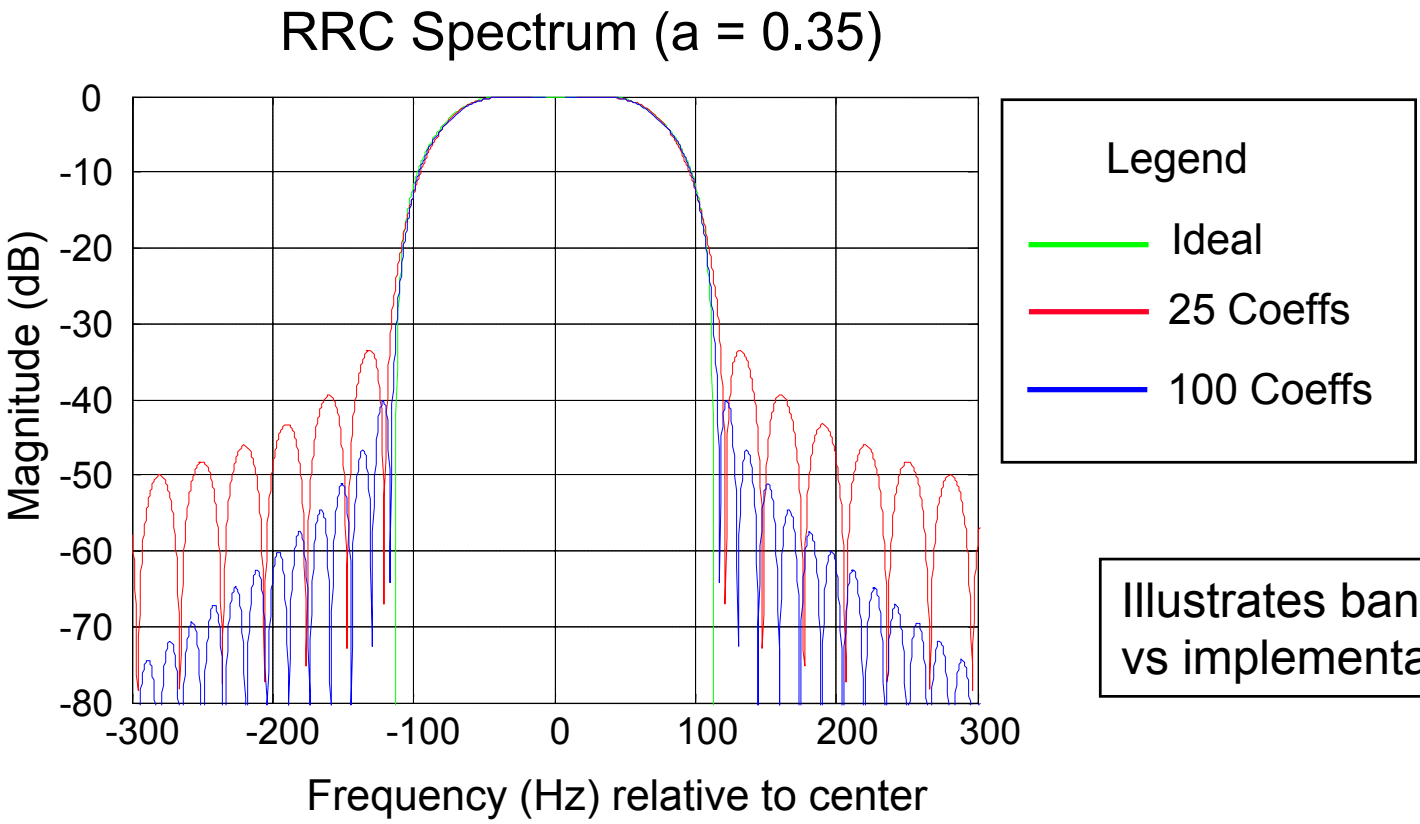



- RRC filtering would be performed on data collected from sensor
- Shift register (tapped delay line) function easily performed on small low cost CPLD/FPGA or in software via microprocessor
- At Rx, CDA employs RRC matched filter detection for best performance



# RRC Implementation Tradeoffs

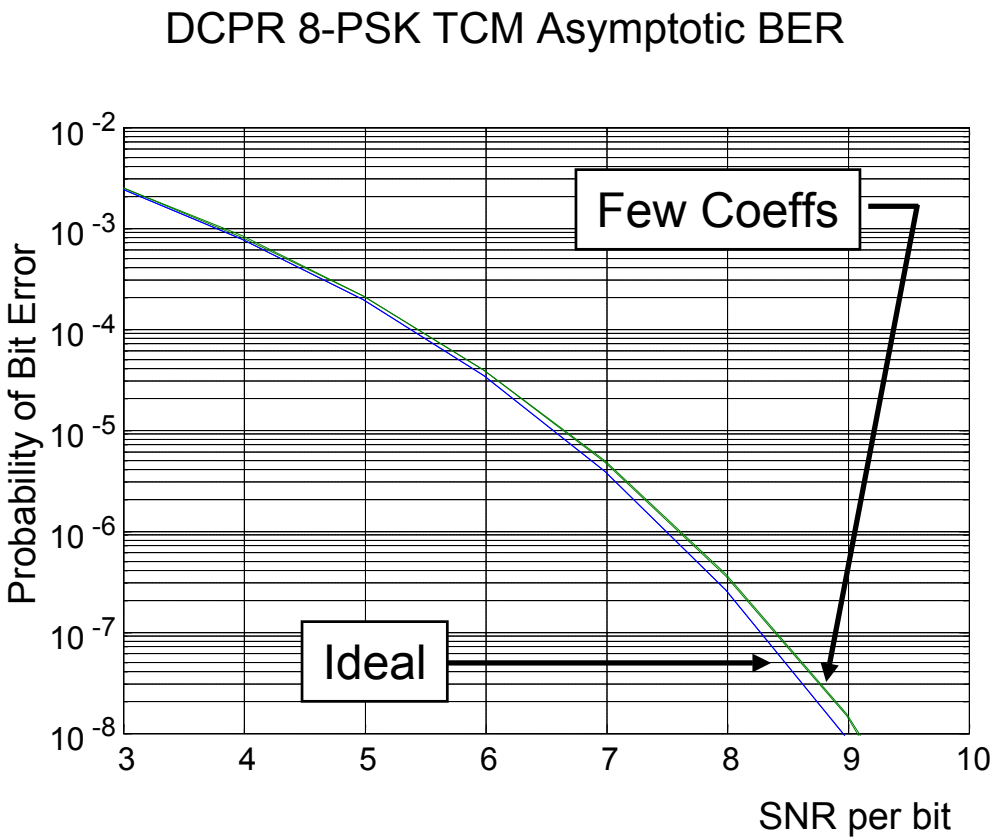
- Practical baseband spectrum approaches theoretical as Coeffs ↑
- 100 Coefficients results in near ideal baseband spectrum




Illustrates bandwidth
vs implementation complexity

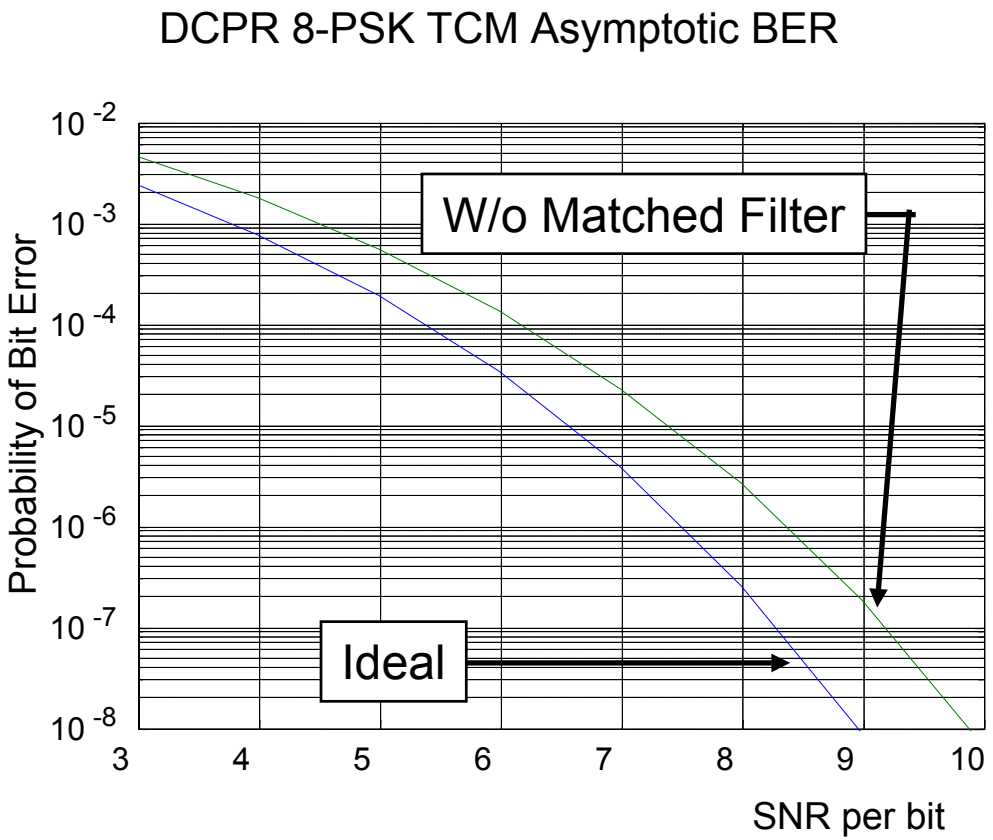
# BER Degradation due to ISI

- Need to consider resulting amount of ISI based on RRC implementation
- In general BER ↓ as number of coefficients ↑
- Relatively few Coefficients results in near ideal BER
  - RRC implementation induces negligible ISI



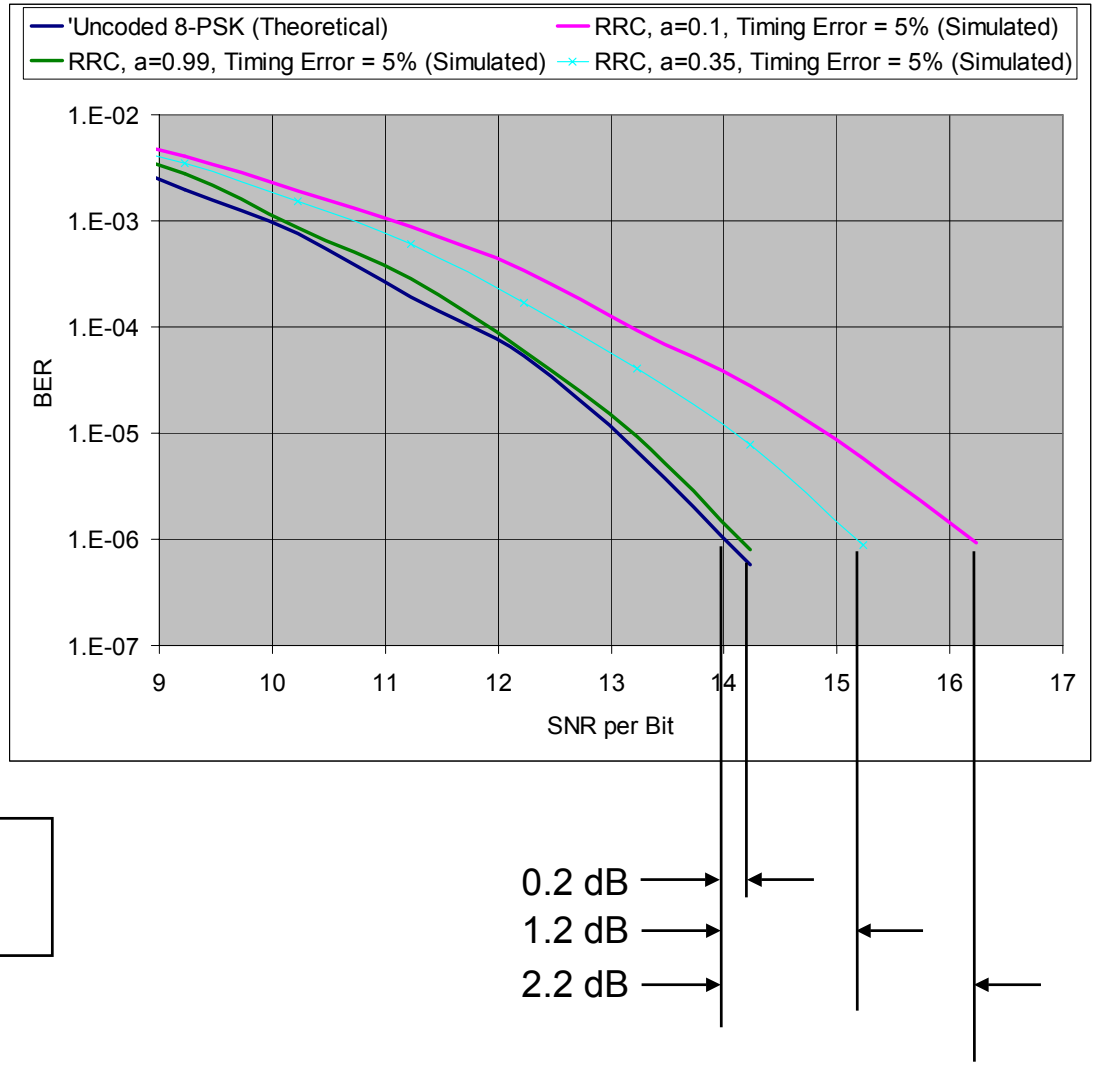
# Matched Filter Mismatch Degrades BER

- Optimal implementation requires that CDA employ matched filter demodulation
  - Filter matched to transmitted RRC waveform
- Without matched filter, loss can be on the order of 1 dB



# RRC Excess Bandwidth Parameter Tradeoffs

- As excess bandwidth parameter ↑
  - Spectral efficiency ↓
  - Peak to average ratio ↓
  - Sensitivity to ISI ↓




Example: RRC sensitivity to timing error

# Power Level Considerations Part I

- DCP Transmit Power Levels
  - Keep at current levels to minimize changes to DCPs
    - Avoid need for new antennas, larger power amplifiers, etc.
- Satellite Power Levels
  - Dynamic range of input signal
  - Average power through satellite
    - Power limitations on AGC circuitry and amplifier
  - Transmit Power Levels
    - Need to ensure compliance with PFD requirements
      - Neg 154 dBW per $m^2$ per 4 KHz
    - Current levels ~ 10 dB lower when channels fully loaded

# Power Level Considerations Part II

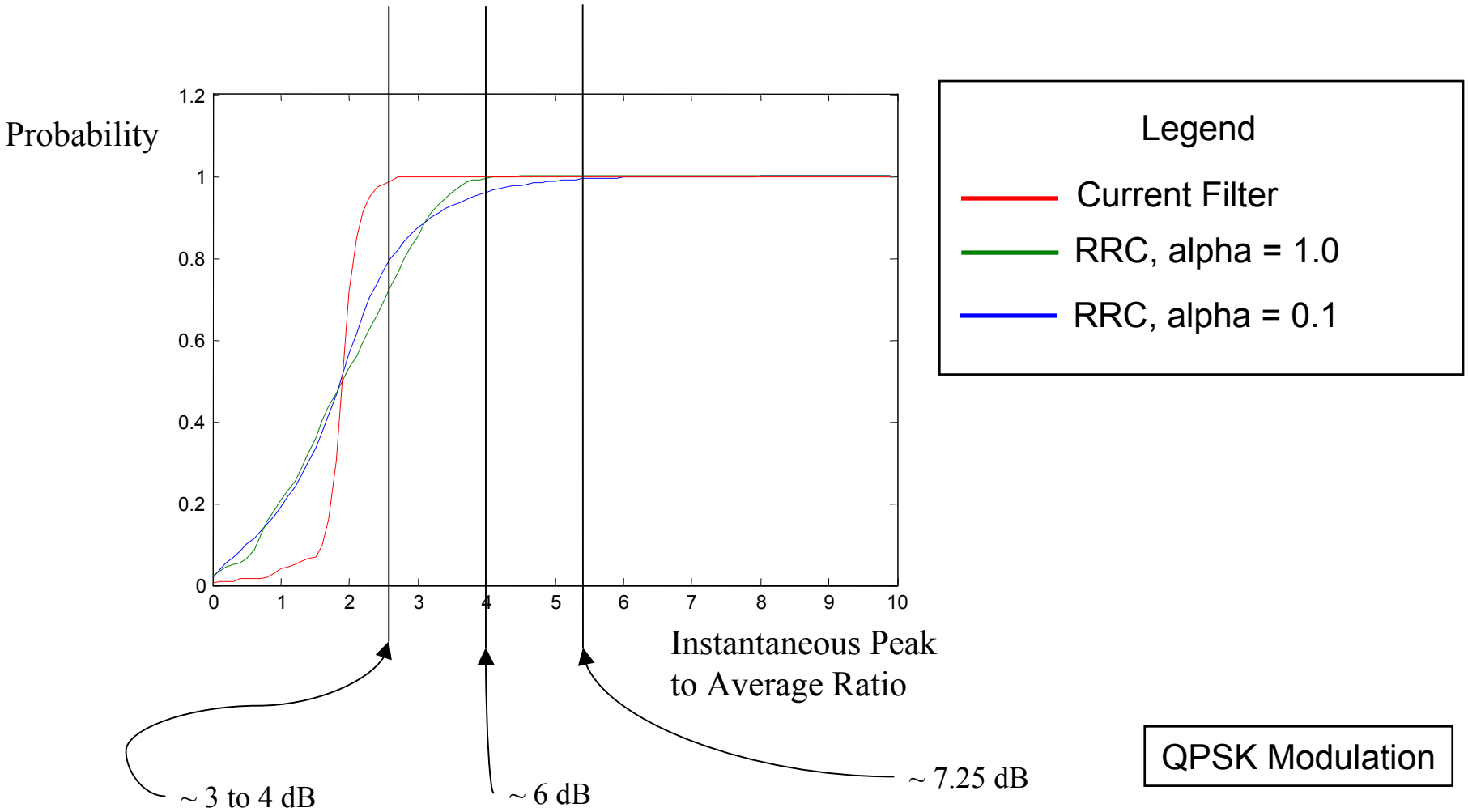
- Need to consider the satellite [and DCP] power amplifier when considering RRC filtering
- Signals with lower peak to average ratios perform better when considering nonlinear amplifiers
- Consideration illustrated via examples:
  - Case I: Infinite BW & Rectangular Pulses
    - Results in ideal constant envelope modulation for PSK transmissions
    - True regardless of QPSK, 8-PSK, OQPSK, …, etc.
    - Ratio of the peak to average signal power level = 2
    - This is the best obtainable
  - Case II: Filtered Rectangular Pulses
    - Filtering employed since finite bandwidth available
    - Filtering results in waveform that is no longer constant envelope
    - Peak to average ratio becomes larger than 2
    - Actual peak to average ratio dependent on amount of filtering applied and modulation type (OQPSK vs QPSK, etc).

# Power Level Considerations Part II (con't)

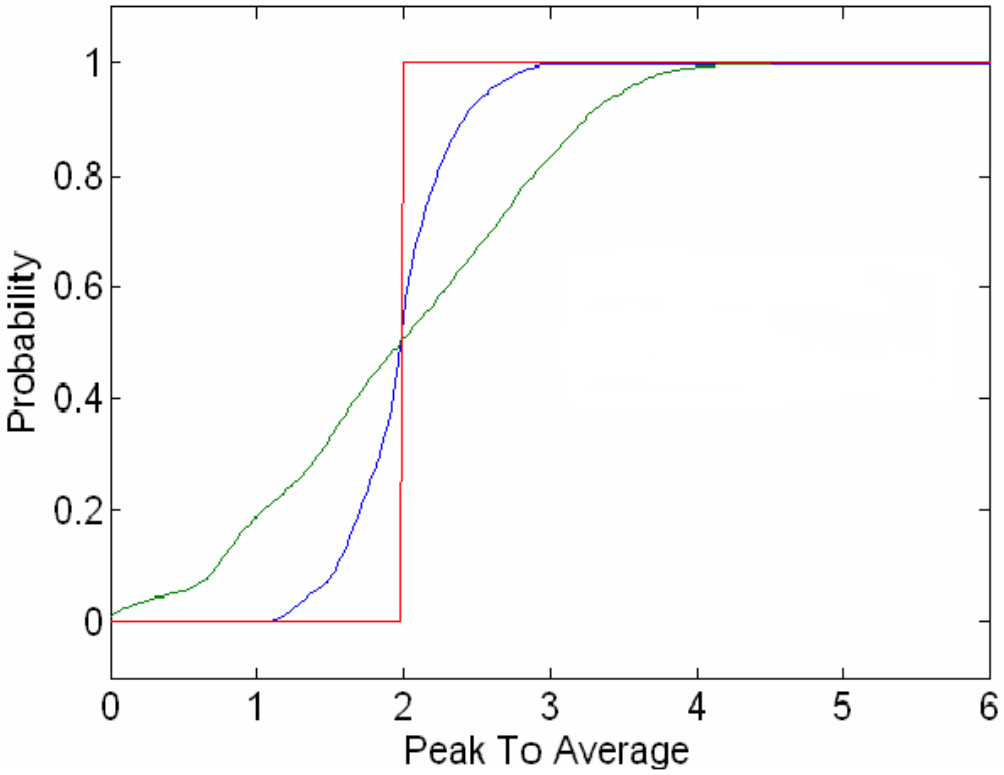
- Case III: RRC Pulses
  - Envelope is inherently not constant
  - Peak to average ratio > 2
  - Peak to average ratio ↓ as excess bandwidth parameter ↑

- As the peak to average ratio ↑ and the average power → amplifier compression point:
  - Distortion to waveform more likely to happen
  - Distortion occurs since some portions of the transmitted signal will undergo saturation due to amplifier
  - Distortion results in transmitted waveform not being equal to waveform used in the matched filter
    - This results in ISI which degrades BER
- Summary
  - Need to consider where satellite and DCP high power amplifiers operate
    - If they typically operate close to amplifier nonlinear region then need to consider this when finalizing RRC parameters

# Peak to Average Ratio CDF



# Peak to Average Ratio CDF




Legend

- RRC, alpha = 1.0, OQPSK
- RRC, alpha = 1.0, 8-PSK
- Ideal Rectangular Pulse

OQPSK helps by reducing peak to average by ~ 1.2 dB

# Summary

- Root Raised Cosine
  - Root Raised Cosine filtering results in system that achieves better spectral efficiency
  - Use of RRC filtering with 1200 bps signal may drive ground platform power amplifier into saturation
  - RRC results in higher peak to average
    - Constant envelope modulation or more linear amplifiers may be required
  - Low cost estimates to upgrade transmitters (DCPs) and receiver